Heat stress of current in-service and proposed prototype rainsuits for the Canadian Forces

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Abstract

This study examined the heat stress associated with wearing the current (C) in-service rainsuit and two new prototype suits. The first prototype (B, which represented the manufacturer's initial) was an antistatic breathable nylon laminated with carbon fibre and carried the Canadian disruptive pattern (CADPAT). The second prototype (S, again the manufacturer's initial) was made of lightweight rubber with CADPAT on neoprene. Seven males performed a familiarization trial and three randomly ordered experimental trials that involved wearing C, B or S over combat clothing and walking at 5.9 km/h on a treadmill with a 2% grade for 3 hours in an environment controlled at 20°C with 90% relative humidity. All subjects completed the 3 hours of exercise while wearing the rainsuits. Physiological strain was the greatest with suit S. Over the 3 hours of exercise, heart rates were significantly higher for S (127.5 ± 29.6 b·min^{-1}) compared with B (119.4 ± 34.4 b·min^{-1}) or C (119.8 ± 25.9 b·min^{-1}). In addition, core temperature was significantly greater over the last 90 min of the exposure for S compared with B and for the last 50 min for S compared with C. The core temperatures were also significantly different between B and C for the last 40 minutes of the test. By the end of the session, core temperature had increased to 38.2 ± 0.4°C, 38.0 ± 0.4°C and 37.9 ± 0.4°C for S, C and B, respectively. The rate of sweat evaporation was greatest for B (0.38 ± 0.03 kg·hr^{-1}) compared with C (0.27 ± 0.05 kg·hr^{-1}) or S (0.31 ± 0.05 kg·hr^{-1}). It was concluded that suit B, a water vapour permeable nylon prototype, evoked the least physiological stress for the body and on that basis only would be the product of choice to serve as a replacement for the current rainsuit (suit C) in use by the CF.

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Résumé

L'étude en question a évalué le stress thermique associé au port de la tenue imperméable réglementaire (C) et de deux nouveaux prototypes. Le premier prototype (B, correspondant à l'initiale du fabricant) est composé de nylon antistatique perméable à l'air et à fibre de carbone intégrée arborant le dessin de camouflage canadien (DCamC). Le deuxième prototype (S, correspondant à l'initiale du fabricant) est constitué de caoutchouc léger et d'une couche de néoprène arborant le dessin de camouflage canadien. Sept hommes ont exécuté un essai de familiarisation et trois essais expérimentaux qui consistaient à porter, dans un ordre aléatoire, les vêtements C, B ou S sur la tenue de combat et à marcher durant 3 heures à 5,9 km/h sur un tapis roulant ayant une inclinaison de 2 %, dans un environnement contrôlé à 20 °C et à 90 % d'humidité relative. Tous les sujets portaient la tenue imperméable lorsque l'exercice de 3 heures a pris fin. La tenue S est celle qui a nécessité un effort physiologique le plus élevé. Au terme des 3 heures d'exercice, les fréquences cardiaques étaient considérablement plus élevées avec la tenue S (127,5 ± 29,6 $b \cdot min^{-1}$) qu'avec les tenues B (119,4 ± 34,4 $b \cdot min^{-1}$) ou C (119,8 ± 25,9 $b \cdot min^{-1}$). Durant les 90 dernières minutes de l'expérience, la température corporelle des sujets était considérablement plus élevée avec la tenue S qu'avec la tenue B; durant les 50 dernières minutes, elle était également plus élevée avec la tenue S qu'avec la tenue C. L'écart observé avec les tenues B et C était aussi considérable durant les 40 dernières minutes de l'essai. À la fin de l'exercice, la température corporelle des participants avait augmenté à 38,2 ± 0,4°C, 38,0 ± 0,4°C et 37,9 ± 0,4°C pour les tenues S, C et B respectivement. Le taux d'évaporation de la sueur était plus élevé avec la tenue B (0,38 ± 0,03 $kg \cdot h^{-1}$) qu'avec les tenues C (0,27 ± 0,05 $kg \cdot h^{-1}$) ou S (0,31 ± 0,05 $kg \cdot h^{-1}$). Il a été conclu que la tenue B, un prototype en nylon perméable à la vapeur d'eau, est celle qui impose le moins de contraintes physiologiques et qui constitue, selon ce critère seulement, la meilleure option si la tenue imperméable réglementaire (C) des FC devait éventuellement être remplacée.

Executive summary

The Directorate of Land Requirements (DLR) is interested in the consequences of thermal stress induced by two new rainsuit prototypes as well as the current in-service model. Their intent was to take advantage of advances made in material sciences, especially in the area of moisture management, in order to make appropriate decisions about potential replacement. DRDC Toronto was tasked to advise on any differences between the current issue and the two prototypes. The current in-service suit (C) is basically made of a light rubber compound. The first prototype (B, which stands for the manufacturer's initial) is an antistatic breathable nylon laminated with carbon fibre and carries the Canadian disruptive pattern (CADPAT). The second prototype (S, again the manufacturer's initial) is a lightweight rubber with CADPAT on neoprene. Seven males performed a familiarization trial and three randomly ordered experimental trials that involved wearing C, B or S over combat clothing and walking at a forced march pace for 3 hours in an environment controlled at 20°C with 90% relative humidity. All subjects completed the 3 hours of exercise while wearing the rainsuits. Physiological strain was the greatest with suit S as indicated by the significantly greater elevations in heart rate and body temperature throughout the exercise period. Suit B promoted the greatest evaporation of sweat and, therefore, loss of heat from the body. There was no difference in the perception of thermal strain among the three rainsuits. Although physiological strain was reduced for suit B compared with C the differences were not great. Nevertheless, if a replacement must be chosen for the current in-service rainsuit then suit B would be suit of choice over suit S on the basis of heat stress alone.

Pope JI, Sleno, N.J., McLellan T.M, Narlis C., Bossi, L.L., Thompson, J.J., and Adam J.J. 2003. Heat stress of current in-service and proposed prototype rainsuits for the Canadian Forces. DRDC Toronto TR 2003-083. Defence R&D Canada – Toronto.

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La Direction des Besoins en ressources terrestres (DBRT) désire évaluer les conséquences attribuables aux contraintes thermiques de deux nouveaux prototypes de tenues imperméables et du modèle réglementaire. L'intention de l'étude était de bénéficier des progrès liés à la science des matériaux et, plus particulièrement, à la gestion de l'humidité afin d'effectuer un choix éclairé si la tenue actuelle devait être remplacée. RDDC-Toronto a été chargé de signaler toutes les différences observées entre la tenue réglementaire et les deux prototypes. La tenue imperméable réglementaire (C) est principalement constituée d'un composé de caoutchouc léger. Le premier prototype (B, correspondant à l'initiale du fabricant) se compose d'un nylon antistatique perméable à l'air à fibre de carbone intégrée arborant le dessin de camouflage canadien (DCamC). Le deuxième prototype (S, correspondant à l'initiale du fabricant) est fait de caoutchouc léger et d'une couche de néoprène arborant le dessin de camouflage canadien. Sept hommes ont exécuté un essai de familiarisation et trois essais expérimentaux qui consistaient à porter, dans un ordre aléatoire, les vêtements C, B ou S sur la tenue de combat et à marcher à une vitesse accélérée durant 3 heures, dans un environnement contrôlé à 20 °C et à 90 % d'humidité relative. Tous les sujets portaient toujours la tenue imperméable lorsque l'exercice de 3 heures a pris fin. La tenue S a nécessité un effort physiologique plus exigeant, tel que l'illustrent la fréquence cardiaque et la température corporelle qui étaient considérablement plus élevées pour la durée de l'essai. La tenue B a permis une meilleure évaporation de la sueur et, du même coup, l'organisme a pu mieux éliminer sa chaleur. Au niveau de la fatigue attribuable à la chaleur, aucune différence n'a été perçue entre les trois tenues. Même si l'effort physiologique avec la tenue B était moins élevée qu'avec la tenue C, les différences ne sont pas considérables. Néanmoins, si la tenue actuelle devait être remplacée, la tenue B serait privilégiée à la tenue S en raison de leurs contraintes thermiques respectives.

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1. Introduction

Military environments frequently necessitate the wearing of protective outerwear, especially when carrying out tasks in threatening environmental conditions. These extra layers of protective gear can severely reduce an individuals ability to maintain a comfortable body temperature by impeding the transfer of heat to the external environment through the process of sweating. This increase in heat storage manifests itself with physiological increases in heart rate, and rectal and skin temperatures in an attempt to maintain normal thermoregulation. These increases usually lead to a voluntary slowing of work pace or rhythm resulting in longer times to achieve task objectives. (McLellan et al., 1993)

The Directorate of Land Requirements (DLR) is interested in the consequences of thermal stress induced by two new rainsuit prototypes as well as the current in-service model. Their intent was to take advantage of advances made in material sciences, especially in the area of moisture management, in order to make appropriate decisions about potential replacement. DRDC Toronto has been tasked to advise on any differences between the current issue and the two prototypes.

The current in-service suit (C) is basically made of a light rubber compound. The first prototype (B, which stands for the manufacturer's initial) is an antistatic breathable nylon laminated with carbon fibre and carries the Canadian disruptive pattern (CADPAT). The second prototype (S, again the manufacturer's initial) is a lightweight rubber with CADPAT on neoprene. More specific information regarding suitability from field trial data can be obtained from a recently published report (Ho et al., 2003).

Few heat stress studies have been done on lightweight encapsulating clothing such as a rainsuit. Studies on encapsulating protective clothing that demonstrate severe reductions on work performance in hot environments are well documented (Cheung et al., 2000). Although these provide relevant information to define degrees of heat stress consequence, specific information is required on the Canadian military rainsuit options. The two suits were specifically built with identical design specifications and differed only in the type of materials used. They were both alternated with the current version in extensive field trials involving regular force personnel under typical operational weather conditions to get subjective impressions from the end-user of their suitability (Ho et al., 2003).

The aim of this study was to provide DLR with the scientific information regarding the thermal strain imposed on the user by the current issue and proposed prototypes, in order to assist them with equipment acquisition decisions and implementation plans.

2. Methods

2.1 Subjects

Following approval from DRDC-Toronto's Human Research Ethics Committee, seven males volunteered to participate in the study. Mean values (±S.D.) for age, height, weight, % body fat and $\dot{V}O_{2peak}$ were 26.9 ±7.01 y, 179.6 ±7.8 cm, 81.7 ±8,8k g, 14.9 ±4.8% and 3.78 ±0.54 $L \cdot min^{-1}$ or 46.2 ±4.97 $ml \cdot kg^{-1} \cdot min^{-1}$, respectively. Subjects were given full details of the experimental protocol and any possible risks or discomforts. After medical approval for participation, each subject gave informed consent before the first day of testing.

2.2 Determination of peak aerobic power ($\dot{V}O_{2peak}$)

$\dot{V}O_{2peak}$ was determined on a motor-driven treadmill using open-circuit spirometry (McLellan et al., 1993) prior to the experimental exposures. After three minutes of running at a self-selected speed, the treadmill grade was increased $1\% \cdot min^{-1}$ until the subject was unable to continue further. $\dot{V}O_{2peak}$ was defined as the highest oxygen consumption ($\dot{V}O_2$) observed during the incremental test. Heart rate (HR) was determined from a telemetry system (Polar Electro PE3000, Stamford, CT). The value obtained at the end of the test was defined as the subject's maximum heart rate (HR_{max}).

2.3 Experimental design

All subjects performed three experimental sessions in random order separated by a minimum of 4 days with the majority of trials done on a weekly basis. The trials were performed in the morning hours starting around 0800hrs. The study was conducted during the summer months of July and August due to scheduling difficulties, thus the degree of potential heat acclimation of the subjects could not be determined. Each subject wore underwear, T-shirt, running shorts, socks, lightweight cotton combat shirt and pants and jogging shoes. In addition, they donned a rainsuit, both top and bottom, with the hood up covering the head.

All sessions involved exposure to 20°C and 90% relative humidity with wind speed $\leq 0.1 m \cdot s^{-1}$ while walking at 5.9 $km \cdot hr^{-1}$ on a treadmill with a 2% grade. The exercise continued for a maximum of 3 hours or until rectal temperature (T_{rec}) reached 40°C, heart rate remained at or above 95% of HR_{max} for 3 minutes (min), nausea or dizziness precluded further exercise, the subject asked to be removed from the chamber or the investigator terminated the trial. Subjects were offered 5 $ml \cdot kg^{-1}$ of cool (~15°C) water every 30 min during the exercise session to maintain adequate hydration. Subjects also performed a familiarisation session about 1 week before the experimental trials that involved the procedures and clothing as described, minus the rainsuit.

2.4 Dressing and weighing procedures

Subject preparation including the measurement of pre-exposure nude and dressed weights, insertion of the rectal thermistor and placement of skin thermistors have been detailed previously (McLellan et al., 1993, Aoyagi et al., 1994). Upon entry to the chamber, the thermistors and rectal thermistor monitoring cables were connected to a computerized data acquisition system (Hewlett-Packard 3497A control unit, 236-9000 computer and 2934A printer) and the exercise began. T_{rec} and skin temperatures were averaged and printed every minute. A 7-point weighted mean skin temperature (T_{msk}) (Hardy et al., 1938) was calculated and printed every minute. HR was recorded every 5 min from a telemetry unit (Polar Electro PE3000, Stamford, CT). Dressed weight was recorded immediately upon exit from the chamber and nude weight was recorded after a short undressing procedure.

Differences in nude and dressed weights before and after each trial were corrected for respiratory and metabolic weight loss (see below). The rate of sweat production was calculated as the difference between corrected pre- and post-trial nude weights, divided by the exercise time that was the total time spent on the treadmill. Evaporative sweat loss was calculated as the difference between corrected pre and post trial dressed weights. Evaporative efficiency, defined as the percentage of sweat produced that was actually allowed to evaporate externally of the suit, was also calculated.

2.5 Gas exchange analyses

During each session, open-circuit spirometry was used to determine expired ventilation and oxygen consumption ($\dot{V}O_2$) using a 2-min average obtained every 15 min. Respiratory water loss was calculated using the $\dot{V}O_2$ measured during the trial and the equation presented by Mitchell et al. (1972). Metabolic weight loss was calculated from the $\dot{V}O_2$ and the respiratory exchange ratio using the equation described by Snellen et al. (1966).

2.6 Ratings of Perceived Exertion and Thermal Comfort

Following the gas exchange measurement, subjects were asked to provide a rating of perceived exertion (RPE) between 6 and 20 for the whole body (Borg, 1972) and a rating of thermal comfort (RTC) between 1 (so cold I am helpless) and 13 (so hot I am sick and nauseous) for the whole body (Hollies et al., 1977).

2.7 Statistical analyses

Data are presented as mean values and standard deviations. A one factor (rainsuit) repeated measures ANOVA was used to evaluate differences in the dependant variables of sweat rate, evaporation rate, evaporative efficiency and exercise time. A two factor (rainsuit by time) repeated measures ANOVA was used to compare the responses for the dependant variables of HR, T_{rec}, T_{msk}, $\dot{V}O_2$, RPE and RTC over time. The Huynh-Feldt correction factor was applied to adjust for any violations in the assumption of sphericity with the repeated factor.

When a significant F-ratio was obtained, a Newman-Keuls post-hoc analysis was used to isolate differences among treatment means. The 0.05 significance level was used for all analyses.

3. Results

3.1 Endurance time

All subjects completed the maximum allowable exercise time of 180 min, before approaching physiological cutoffs or complaining of ill-feeling, although physical fatigue was very prevalent.

3.2 Heart rate

Figure 1 illustrates a significantly higher HR response for suit S compared to either suit B or C from 75 min to the end of the trial. Mean values ± S.D. over the entire 3 hours for the B, C and S sessions were 119.4 ±34.4, 119.8 ±25.9, and127.5 ±29.6 b·min^{-1}, respectively.

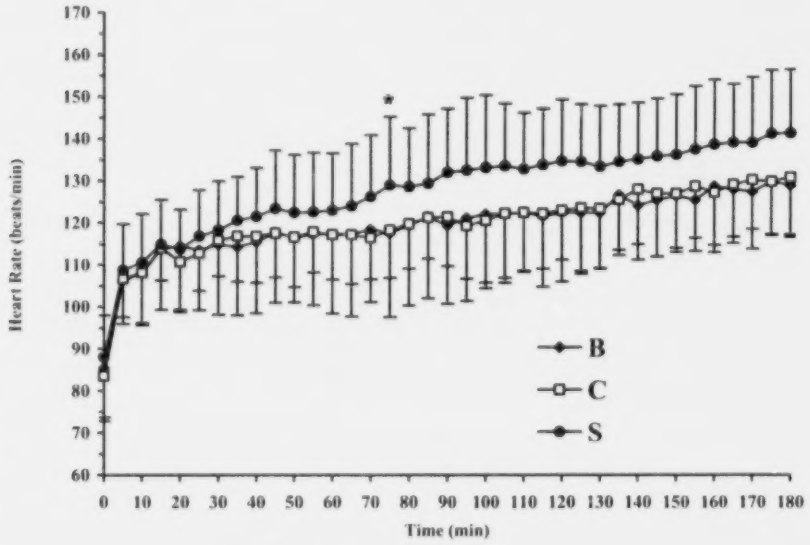
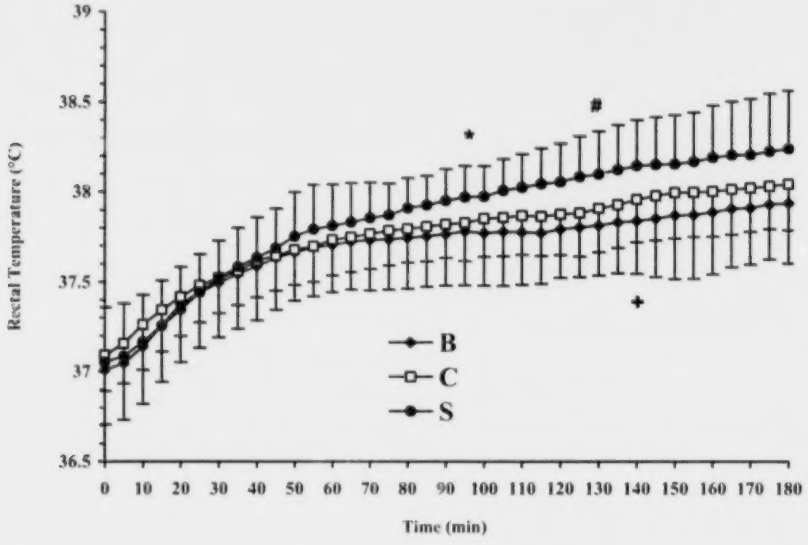


Figure 1. *Heart rate responses during the experimental exposures while wearing the B (representing the first initial of the manufacturer), C (the current in-service) or S (representing the first initial of the manufacturer) rainsuit over combat clothing. Values are mean±SD for n=7 to 180 min. The '*' denotes start of significant difference to the end of the trial between S and both B and C.*

3.3 Rectal temperature

Figure 2 depicts a significantly higher T_{rec} response for suit S compared to suit B from 95 min,and for suit C from 130 min to the end of the trial. In addition, T_{rec} response for suit C was significantly greater than for suit B from 140 min to the end of the trial.



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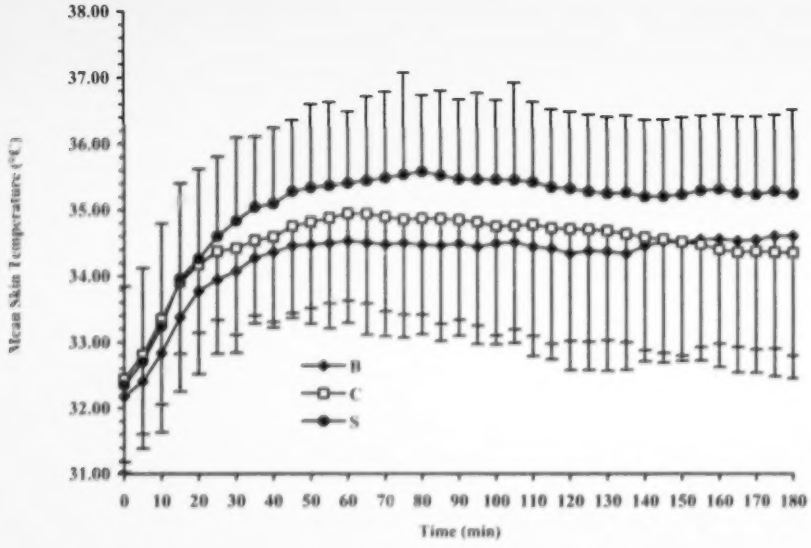
3.4 Mean skin temperature

Figure 3 illustrates the T_{msk} response over time for the three rainsuits evaluated. There were no significant differences obtained between the suits although suit S appeared to be marginally higher than either suit B or C. Mean values (± S.D.) over the 3 hours for the B, C and S sessions were 34.2 ±3.2 °C, 34.5 ±3.4 °C and 34.9 ±2.6 °C, respectively.



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3.5 Oxygen consumption

$\dot{V}O_2$ was not significantly different among the three rainsuits (1.59 ±0.23 L·min^{-1}, 1.58 ±0.16 L·min^{-1} and 1.64 ±0.22 L·min^{-1} for the B, C and S sessions, respectively). There was a main effect of time indicating that oxygen consumption increased over the course of the experimental exposure, but did so in similar fashion for the three rainsuits.

3.6 Ratings of Perceived Exertion and Thermal Comfort

RPE was not different among the rainsuits over the course of the exposure but did increase significantly from 10.3 ±0.9 at the beginning of the trial to 13.1 ±1.1 at the end. Similarly, RTC was not different among the rainsuits during the exposure but did increase significantly from 7.9 ±0.4 at the start of the trial to 9.3 ±0.7 at the end.

3.7 Sweat production, evaporation rate and evaporative efficiency

Table 1 depicts the rate of sweat production ($kg \cdot h^{-1}$), evaporation rate ($kg \cdot h^{-1}$) and efficiency (%) during the experimental exposure. Significantly less sweat was produced while wearing suit B and it was more efficient at permitting evaporation than either suit C or S. There were no other significant differences observed.

Table 1. *Sweat rate, evaporation rate and evaporative efficiency for the B (representing the first initial of the manufacturer), C (the current in-service) or S (representing the first initial of the manufacturer) rainsuit worn over combat clothing. Values are means ± SD. The asterisk denotes significant difference between suit B and both suits C and S.*

	B	C	S
SWEAT RATE ($kg \cdot h^{-1}$)	0.63 * ± 0.08	0.77 ± 0.13	0.75 ± 0.11
EVAPORATION RATE ($kg \cdot h^{-1}$)	0.38 * ± 0.03	0.27 ± 0.05	0.31 ± 0.05
EFFICIENCY (%)	63.4 * ± 4.51	35.4 ± 1.76	41.6 ± 4.34

4. Discussion

The purpose of this study was to compare two proposed prototype rainsuits for replacement of the current in-service rainsuit used by the Canadian Forces (CF). One of these (B) was of a nylon nature and therefore was permeable to water vapour. The other (S), including the current suit (C), were of a lightweight rubber and were therefore markedly reduced in their permeability to water vapour. The workload (5.9 $km \cdot hr^{-1}$ at 2% grade) and environmental conditions (20°C and 90% relative humidity) were selected as those that CF personnel would operationally encounter during a forced march of 10km with full kit.

The physiological parameters measured during this study exhibited significantly different responses between the rainsuits for some of the variables and no significant difference for others. The absolute value of any one variable at the end of the experimental trial is not the critical feature in itself. What is of importance are the trends in response between the rainsuits over the time course of the exposure and the implications these have for CF personnel working in these suits.

It seems reasonably fair to loosely rank the suits as B over C over S in terms of progressing from being the least physiologically detrimental to the most. The workload imposed was not overly severe, as it was perceived as being only somewhat hard by the subjects, and was equivalent to their working at approximately 42% of $\dot{V}O_{2\,peak}$. This was reflected in the final HR being approximately 65% of HR_{max}. The experimental exposure was only of 180 minutes duration, and even after this relatively short time, there was a significant increase in HR for suit S over both suits B & C. Had the exercise session lasted for a period of time equivalent to a full day's work or at a higher intensity, it becomes reasonable to expect that HR increase for suit S would continue to be higher and faster than the other two suits. This would cause personnel wearing suit S to become fatigued earlier and to a far greater extent, and might lead to a slowing of work rate thus possibly leading to longer times to achieve a military objective, such as troop movement or completing important tasks, such as establishing a defensive position. This could lead to work/rest schedules that commanders might be hesitant in employing.

This same trend was also apparent for T_{rec} and T_{msk}. T_{rec} showed significant differences among all three suits towards the end of the experimental trial and T_{msk} exhibited the same trend but not to a significant level. Once again, the final physiological values for T_{rec} and T_{msk} were not exceptionally high, but the increasing trend over time for T_{rec} could signify an increase in heat storage with continued exposure and/or an increase in ambient temperature or workrate. The sweat rate, evaporative rate and evaporative efficiency data clearly demonstrate that suit B is superior to the other two suits in its ability to reduce thermal stress and mitigate the soldier's risk of heat injury with more prolonged work.

Combined with HR response, the data indicate a beneficial effect in the order of ranking suit B over suit C over suit S in terms of reducing physiological stress.

It's also noteworthy to look at the results of the study by Ho et al. (2003). This study evaluated more subjective parameters such as comfort of wear, interference with other military gear, ease of packing, moisture management, durability and functionality, just to name a few. Their conclusion was to rank the three suits as prototype B preferable to the current in-service suit C which, in turn, was preferred over prototype S. The objective measurements made in the current study appear to be well supported by the subjective impressions offered by CF personnel actually using these suits in the field for the trial period April to December 2002.

It should be remembered that the wearing of additional impermeable layers over the combat clothing but under the rainsuit, such as a fragmentation protection vest, would have a greater negative effect on suit B compared with the other rainsuits. In other words, the advantages for a lower cardiovascular and thermal strain observed in the present study when suit B was worn would be less evident if a fragmentation protection vest was also worn (McLellan et al., 2003).

5. Conclusions and recommendations

Suit S, a water vapour impermeable prototype, evoked the most negative physiological response to the thermal stress imposed.

Suit C, the current in-service model, was marginally better than suit S in most parameters measured.

Suit B, a water vapour permeable nylon prototype, evoked the least physiological stress for the body and would be the product of choice to serve as replacement for the current rainsuit in use by the CF.

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List of symbols/ abbreviations/ acronyms/ initialisms

ANOVA	Analysis of Variance
B	First Initial of the Manufacturer of Prototype Rainsuit B
C	Current in-service Rainsuit
CF	Canadian Forces
DLR	Directorate of Land Requirements
DRDC	Defence R&D Canada
HR	Heart Rate
HR_{max}	Maximum Heart Rate
Min	minutes
RPE	Rating of Perceived Exertion
RTC	Rating of Thermal Comfort
S	First Initial of the Manufacturer of Prototype Rainsuit S
S.D.	Standard Deviation
T_{msk}	Mean Skin Temperature
T_{rec}	Rectal Temperature
$\dot{V}O_2$	Oxygen Consumption
$\dot{V}O_{2peak}$	Peak Oxygen Consumption

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14. ABSTRACT

(U) This study examined the heat stress associated with wearing the current (C) in-service rainsuit and two new prototype suits. The first prototype (B, which represented the manufacturer's initial) was an antistatic breathable nylon laminated with carbon fibre and carried the Canadian disruptive pattern (CADPAT). The second prototype (S, again the manufacturer's initial) was made of lightweight rubber with CADPAT on neoprene. Seven males performed a familiarization trial and three randomly ordered experimental trials that involved wearing C, B or S over combat clothing and walking at 5.9 km/h on a treadmill with a 2% grade for 3 hours in an environment controlled at 20ºC with 90% relative humidity. All subjects completed the 3 hours of exercise while wearing the rainsuits. Physiological strain was the greatest with suit S. Over the 3 hours of exercise, heart rates were significantly higher for S (127.5 ± 29.6 b·min-1) compared with B (119.4 ±34.4 b·min-1) or C (119.8 ± 25.9 b·min-1). In addition, core temperature was significantly greater over the last 90 min of the exposure for S compared with B and for the last 50 min for S compared with C. The core temperatures were also significantly different between B and C for the last 40 minutes of the test. By the end of the session, core temperature had increased to 38.2 ± 0.4ºC, 38.0 ± 0.4ºC and 37.9 ± 0.4ºC for S, C and B, respectively. The rate of sweat evaporation was greatest for B (0.38 ± 0.03 kg·hr-1) compared with C (0.27 ± 0.05 kg·hr-1) or S (0.31 ± 0.05 kg·hr-1). It was concluded that suit B, a water vapour permeable nylon prototype, evoked the least physiological stress for the body and on that basis only would be the product of choice to serve as a replacement for the current rainsuit (suit C) in use by the CF.

(U) L'étude en question a évalué le stress thermique associé au port de la tenue imperméable réglementaire (C) et de deux nouveaux prototypes. Le premier prototype (B, correspondant à l'initiale du fabricant) est composé de nylon antistatique perméable à l'air et à fibre de carbone intégrée arborant le dessin de camouflage canadien (DCamC). Le deuxième prototype (S, correspondant à l'initiale du fabricant) est constitué de caoutchouc léger et d'une couche de néoprène arborant le dessin de camouflage canadien. Sept hommes ont exécuté un essai de familiarisation et trois essais expérimentaux qui consistaient à porter, dans un ordre aléatoire, les vêtements C, B ou S sur la tenue de combat et à marcher durant 3 heures à 5,9 km/h sur un tapis roulant ayant une inclinaison de 2 %, dans un environnement contrôlé à 20 ºC et à 90 % d'humidité relative. Tous les sujets portaient la tenue imperméable lorsque l'exercice de 3 heures a pris fin. La tenue S est celle qui a nécessité un effort physiologique le plus élevé. Au terme des 3 heures d'exercice, les fréquences cardiaques étaient considérablement plus élevées avec la tenue S (127,5 ± 29,6 b·min-1) qu'avec les tenues B (119,4 ± 34,4 b·min-1) ou C (119,8 ± 25,9 b·min-1). Durant les 90 dernières minutes de l'expérience, la température corporelle des sujets était considérablement plus élevée avec la tenue S qu'avec la tenue B; durant les 50 dernières minutes, elle était également plus élevée avec la tenue S qu'avec la tenue C. L'écart observé avec les tenues B et C était aussi considérable durant les 40 dernières minutes de l'essai. À la fin de l'exercice, la température corporelle des participants avait augmenté à 38,2 ± 0,4ºC, 38,0 ± 0,4ºC et 37,9 ± 0,4ºC pour les tenues S, C et B respectivement. Le taux d'évaporation de la sueur était plus élevé avec la tenue B (0,38 ± 0,03 kg·h-1) qu'avec les tenues C (0,27 ± 0,05 kg·h-1) ou S (0,31 ± 0,05 kg·h-1). Il a été conclu que la tenue B, un prototype en nylon perméable à la vapeur d'eau, est celle qui impose le moins de contraintes physiologiques et qui constitue, selon ce critère seulement, la meilleure option si la tenue imperméable réglementaire (C) des FC devait éventuellement être remplacée.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) core temperature, heart rate, skin temperature, exercise